NASA Earth Science
Data Analysis for Climate Change Decisions

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Data Analysis for Climate Change Decisions

Why NASA?   Why Satellites?

- Ground-based measurements of climate are insufficient and declining … particularly outside of North America and Europe

- Ground-based measurements of climate lack:

  – the uniform calibration needed to assess climate variability and change

  – The ability to see things at remote locations, or over the Earth as a whole
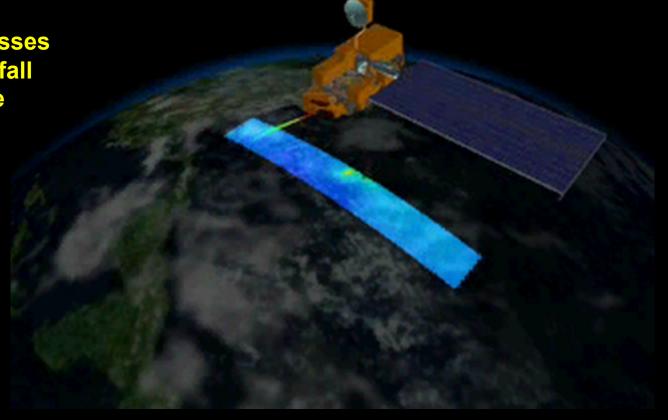
Satellite measurement of Earth properties

Multiple satellites measure a wide variety of earth processes:
winds, temperatures, clouds, pollution, the ocean and land surface.

Data are used for weather and climate predictions

Satellite measurement of Earth properties

- **Cross-track scanners measure:**
  - **Surface temperature (land and sea)**
  - **Atmospheric temperature and humidity**
  - **Plant life (chlorophyll)**
  - **Ocean winds**
  - **Atmospheric gasses**
  - **Clouds and rainfall**
  - **… and lots more**

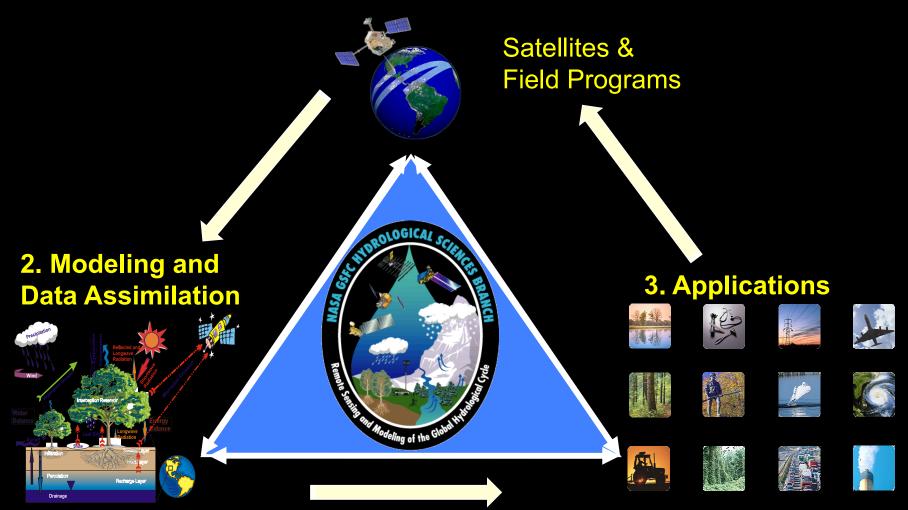- **Data are used for weather and climate predictions**

Satellite measurement of Earth properties

Data from satellites are stitched together in a computer to make a picture of the whole Earth.

NASA satellite data are used worldwide to better understand the Earth and how it operates.

The satellites observe the full Earth more than once a day so we can measure night and day-time events.

We support the NOAA weather service and many other Agencies with our Earth observations.
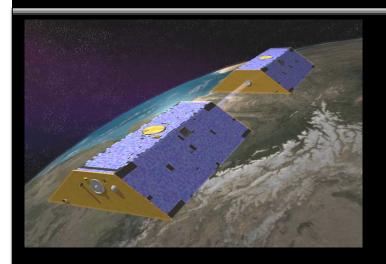
NASA Earth Science
1. Observations

Satellites &
Field Programs

2. Modeling and
Data Assimilation

3. Applications

NOAA, NASA, DOD, JCSDA

Water Management: EPA, USGS, NWS
Security: DHS, USAF, Army, USAID,
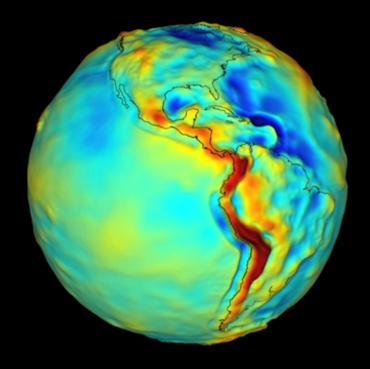Fire warnings

Polar Ice

NASA GRACE*
Gravity Recovery and Climate Experiment

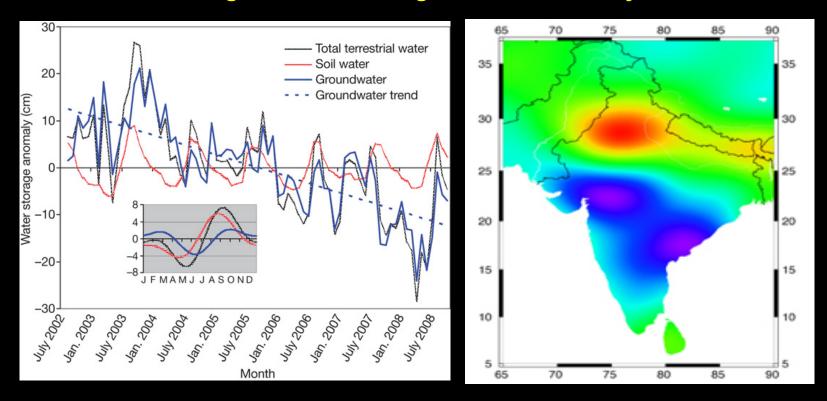**The Gravity Recovery and Climate Experiment measures the Earth gravity field using a pair of satellites.**

Earth's gravity field = geology + oceans + ice sheets + soil moisture + ground water + ...

* GRACE is a joint partnership between NASA and DLR in Germany.

NASA GRACE*
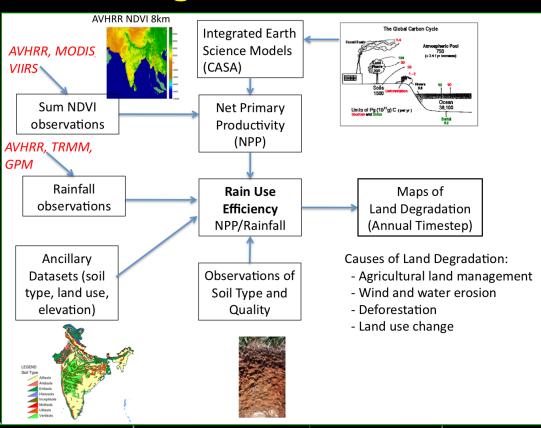# Gravity Recovery and Climate Experiment

India's Disappearing Groundwater: observations by GRACE show regions that are losing centimeters of groundwater each year.
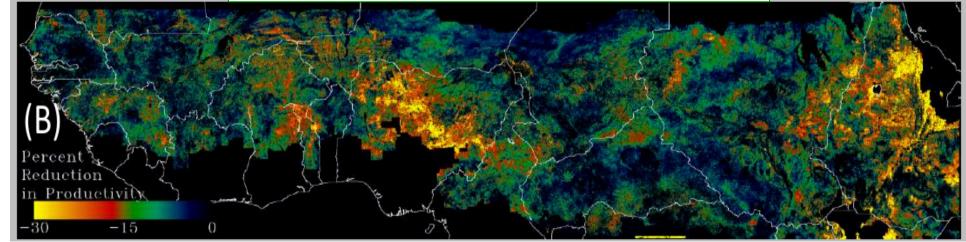

Monthly time series of anomalies of GRACE-derived total TWS, modeled soil-water storage and estimated groundwater storage, averaged over Rajasthan, Punjab and Haryana, plotted as equivalent heights of water in centimeters. Also shown is the best-fit linear groundwater trend. Inset, mean seasonal cycle of each variable. Credit: M. Rodell et al., Satellite-Based Estimates of Groundwater Depletion in India, Nature 460, August 2009
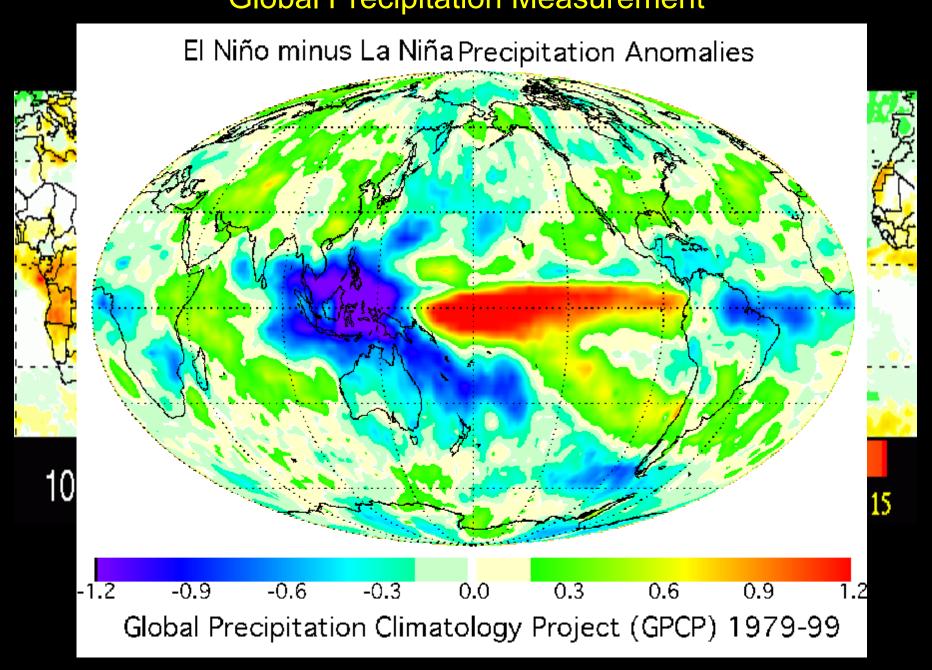
*Joint with DLR, Germany

Soil Degradation Studies
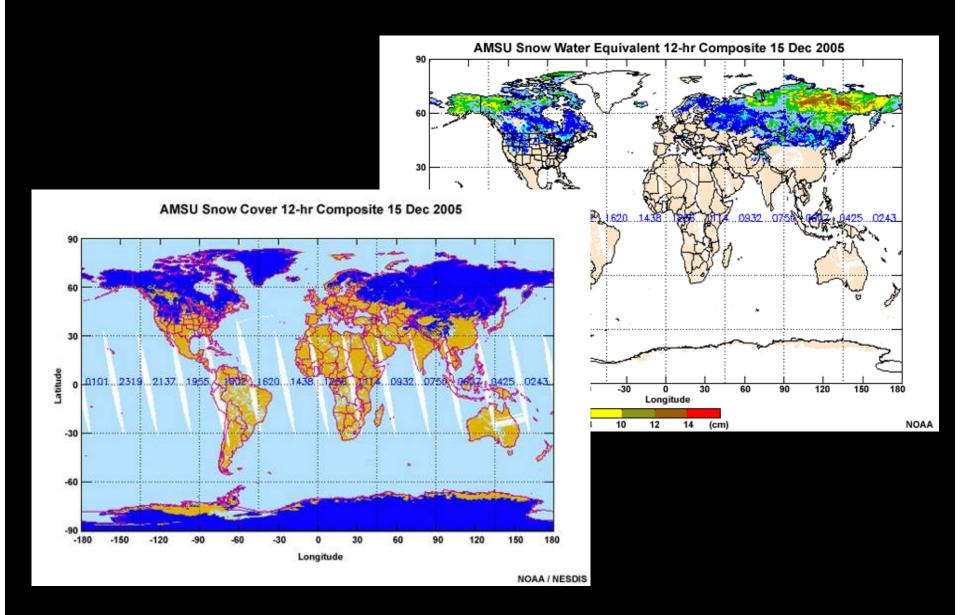
Global Precipitation Measurement

El Niño minus La Niña Precipitation Anomalies

Global Precipitation Climatology Project (GPCP) 1979-99

Snow Cover and Water Content

AMSU Snow Water Equivalent 12-hr Composite 15 Dec 2005

AMSU Snow Cover 12-hr Composite 15 Dec 2005

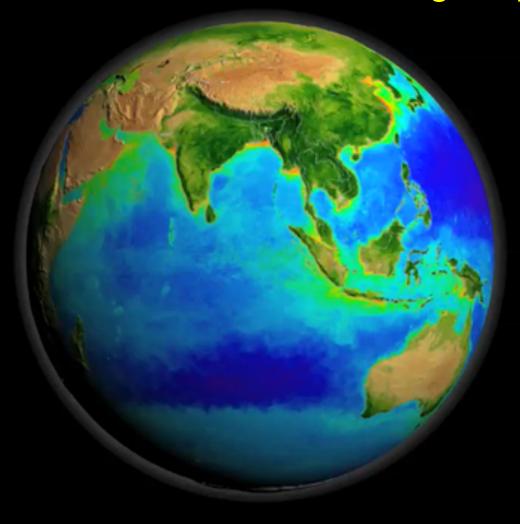NOAA / NESDIS

NOAA

* Advanced Microwave Sounding Unit Instrument, developed by NASA,flown on NOAA polar orbiter satellites

Satellite measurement of Earth biological properties

Chlorophyll *a* Concentration (mg / m^3)

0.01 0.02 0.03 0.04 0.05 0.1 0.2 0.3 0.5 1.0 2.0 3.0 4.0 5.0 10 20 30 40 50 60

Normalized Difference Vegetation Index

-0.05 0.009 0.06 0.12 0.17 0.233 0.287 0.347 0.404 0.461 0.518 0.575 0.632 0.689 0.746 0.803 0.860 0.912

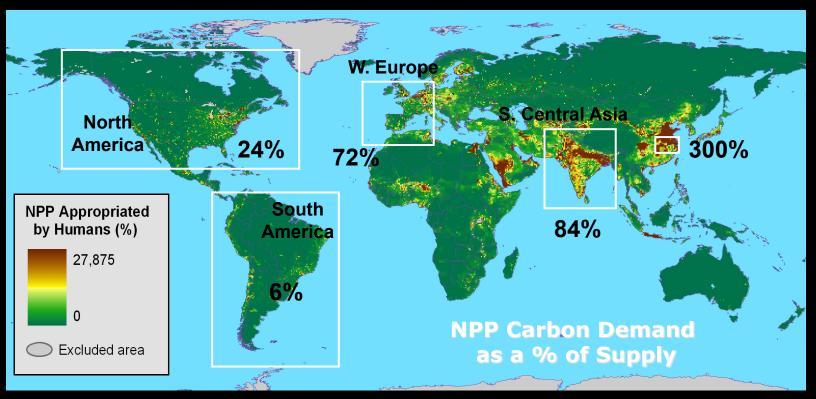# Global Patterns in Human Consumption of Net Primary Production (NPP)

Global NPP Demand is 11.5 Pg C per year (20% of Supply)

There are large regional and local variations

6% (South America) to over 70% (Europe and Asia), and from near 0% (Central Australia) to over 30,000% (New York City, Bejing).
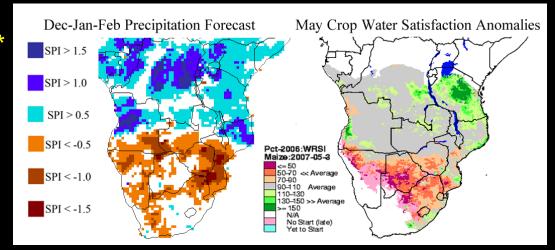

The rate at which humans consume NPP-C is a powerful aggregate measure of human impact on biosphere function.

M. L. Imhoff, et al. **Nature**, 24 June 2004

Famine Warnings Using
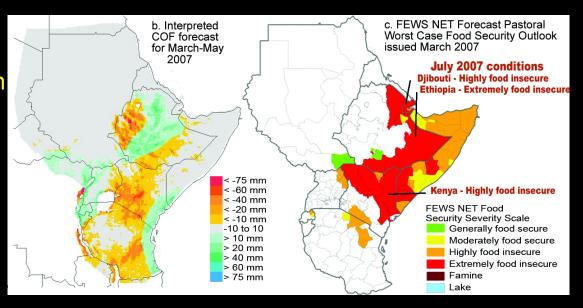# Remote Sensing and Models

Famine Early Warning System*
• biophysical satellite remote sensing
• coupled with models of climate, ecosystem, crop and economic models.

Global climate model:
• predicts future crop production
• integrate with socio-economic information
• enables estimates of future changes in food security for response planning.

Famine Early Warning System (FEWS)

Objectives

- **Improve the use of NASA satellite data in Famine Early Warning Systems Network analysis and decision making processes**

- **Incorporate MODIS vegetation and land surface temperature, total precipitable water and rainfall data.**

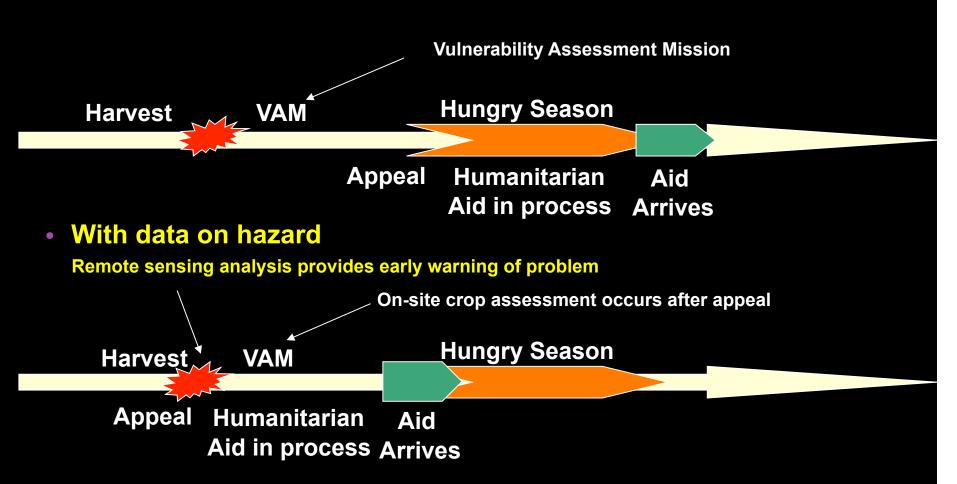- **Development of a new software interface that allowed dynamic comparison of standardized anomalies**

Partners:

USAID, NASA, USGS and University of California, Santa Barbara

Benefits

- **NASA data to assist FEWS NET to anticipate and warn of humanitarian crises**
- **Projecting Rainfall and NDVI data 1-4 months in future for improved decision support.**
- **Integrated climate data for WHO Health Mapper for early identification of malaria epidemics.**

Remote sensing speeds response

- **Current Sequence of Events**

Vulnerability Assessment Mission

Harvest   **VAM**   **Hungry Season**

Appeal   **Humanitarian   Aid
               Aid in process   Arrives**

- **With data on hazard**

Remote sensing analysis provides early warning of problem

On-site crop assessment occurs after appeal

Harvest   **VAM**   **Hungry Season**

**Appeal   Humanitarian   Aid
             Aid in process   Arrives**

Malaria Modeling and Surveillance

Issues:
- 40% of the world's populations at risk
- 300-500 million cases per year
- 1-3 million deaths per year
- One death every 30 seconds
- Significant increases of funding for malaria control and vaccine research have rekindled hope for eradication
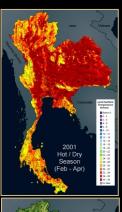

Goals:
- Risk detection: Detection of potential larval habitats
- Risk prediction: Prediction of current and future endemicity
- Risk reduction: Identification of key factors that sustain or promote transmissions

Partners:
- US Armed Forces Research Inst. of Medical Sciences,
- Mahidol Univ.,
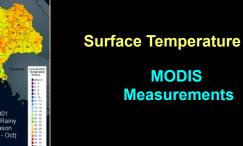- US Navy Medical Research Div.,
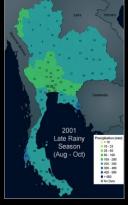- Ministry of Health

Malaria Modeling and Surveillance

Surface Temperature

MODIS Measurements

Vegetation Index

AVHRR & MODIS Measurements

Rainfall

TRMM Measurements
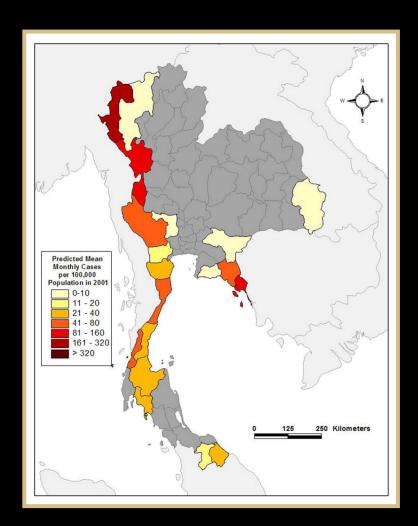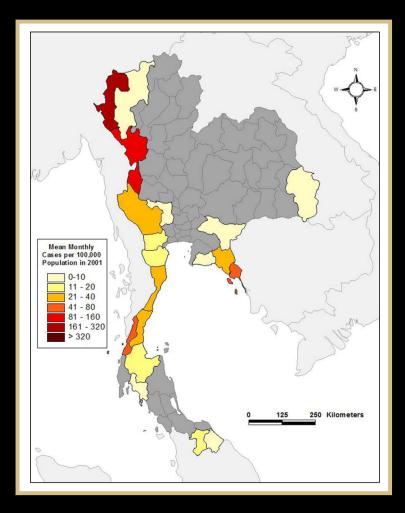
Nov-Jan Cool / Dry

Feb-Apr Hot / Dry

May-Jul Early Rainy

Aug-Sep Late Rainy

Malaria Modeling and Surveillance

Thailand Modeled

Thailand Actual
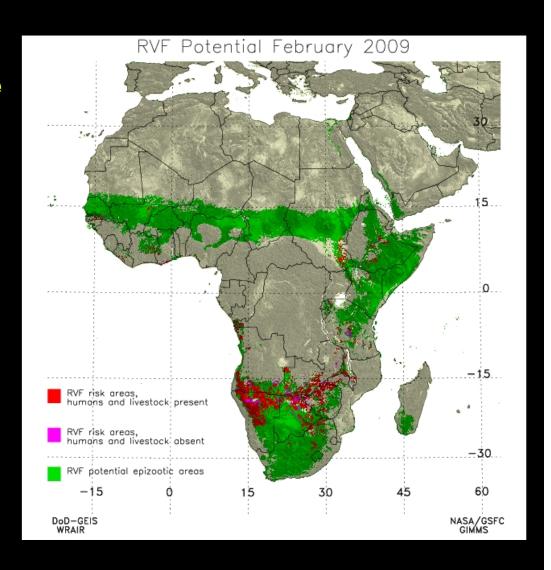
Rift Valley Fever Outbreak Risk

Rift Valley Fever Risk Map (Livestock and human disease transmitted by mosquito)
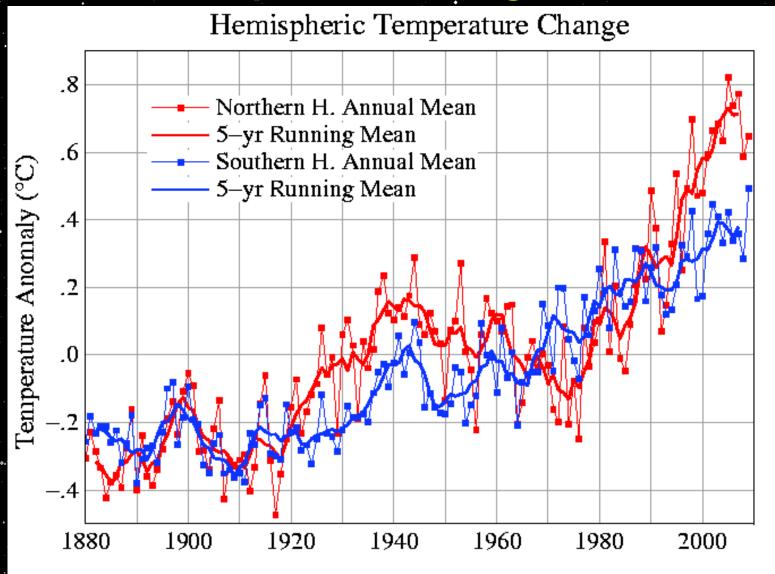
Based on NDVI

Precipitation and Temperature information also used

Sensors: MODIS and AVHRR

RVF Potential February 2009

RVF risk areas, humans and livestock present

RVF risk areas, humans and livestock absent

RVF potential epizootic areas

DoD-GEIS
WRAIR

NASA/GSFC
GIMMS

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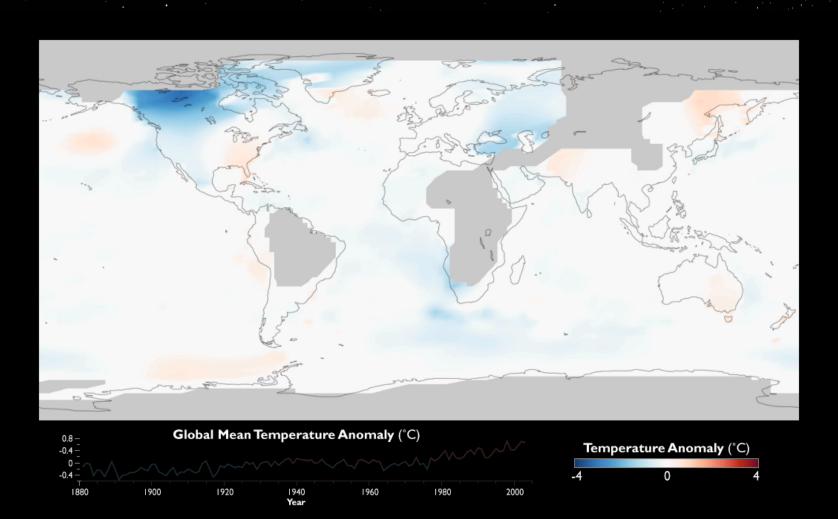
Global Temperature Changes since 1880

Global Mean Temperature Anomaly (°C)

Temperature Anomaly (°C)

Year

Changes in Precipitation

Annual precipitation trends: 1900 to 2000

More Rain

Less Rain

Trends in percentage per century

-50% -40% -30% -20% -10% 0 +10% +20% +30% +40% +50%

Source: IPCC

Decreased snow cover:
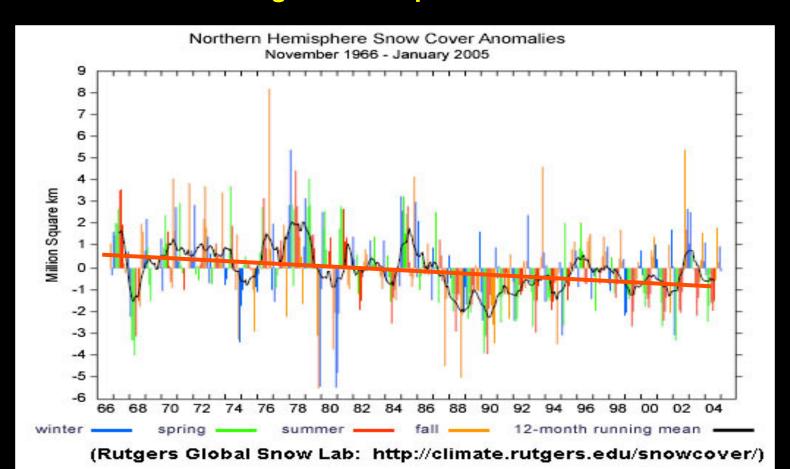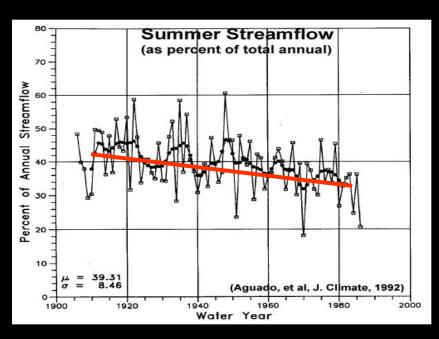- Snow starts later in season
- Snow melts earlier
- Snow cover reduced 1-2 days/yr since early 1970's
- More precipitation is rain
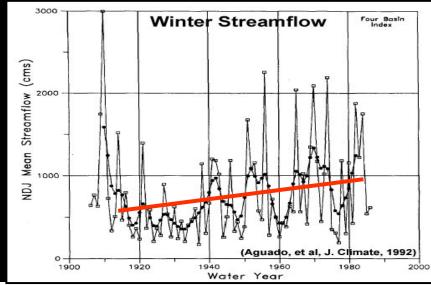- Water storage in snow pack is reduced

Northern Hemisphere Snow Cover Anomalies
November 1966 - January 2005

winter —— spring —— summer —— fall —— 12-month running mean ——

(Rutgers Global Snow Lab: http://climate.rutgers.edu/snowcover/)

Runoff Changes in Spring and Fall

Summer Streamflow (as percent of total annual)
μ = 39.31 σ = 8.46
(Aguado, et al, J. Climate, 1992)

Winter Streamflow — Four Basin Index
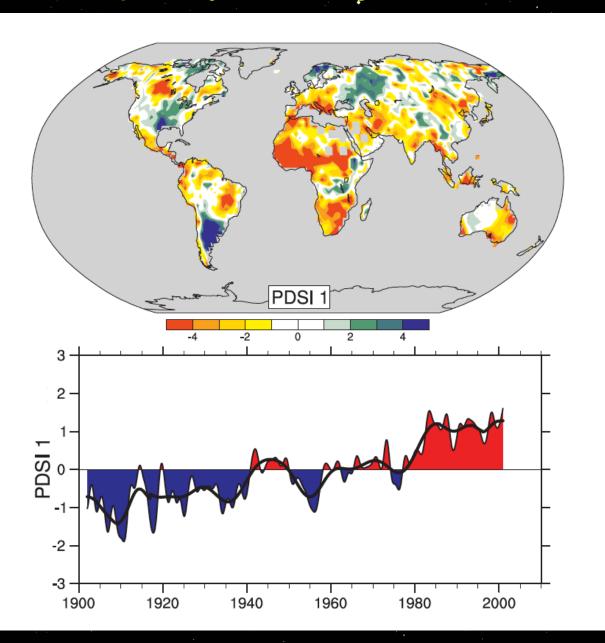(Aguado, et al, J. Climate, 1992)

As temperatures increase:
- More precipitation falls as rain
  - Winter runoff is increased
  - Spring runoff pulse is earlier
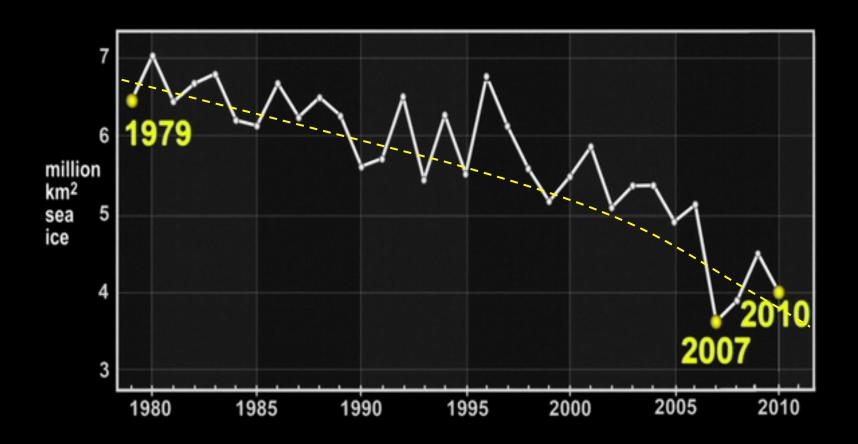 - Summer runoff is decreased

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Ecosystem Impacts:
What does this mean for a farmer?

Concern about climate change effects:
- **Getting snow melt water from the river for irrigation**
- **Getting water in the summer**
- **Urban encroachment**
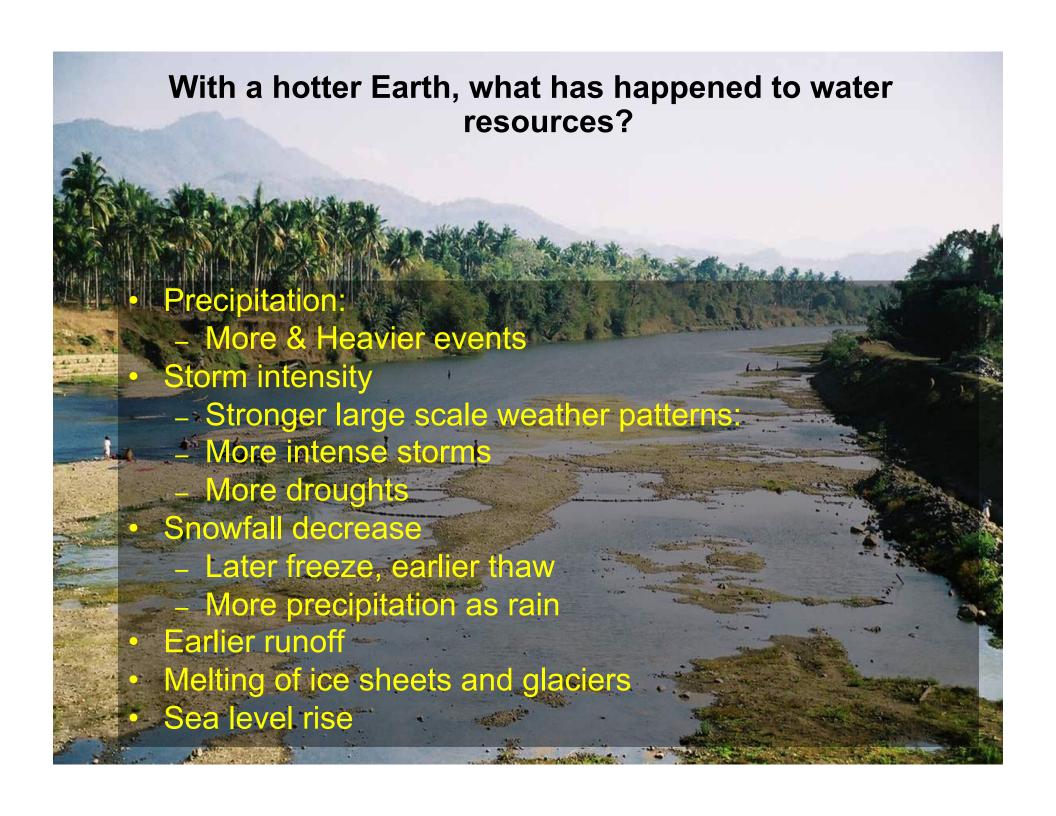
Frequency of drought increases

Arctic Sea Ice

With a hotter Earth, what has happened to water resources?

- Precipitation:
  - More & Heavier events
- Storm intensity
  - Stronger large scale weather patterns:
  - More intense storms
  - More droughts
- Snowfall decrease
  - Later freeze, earlier thaw
  - More precipitation as rain
- Earlier runoff
- Melting of ice sheets and glaciers
- Sea level rise

NASA Earth Science

- *Satellite observations* of Earth's global climate provide:
  - Understanding of climate change forcing:
    - > Radiation, Aerosols, Atmospheric chemistry
  - Understanding of climate change impacts:
    - > Cryosphere, Hydrosphere, Ecosystems

- *We meet national needs* for understanding climate change
  - Develop and operate climate-observing satellites
  - Develop and validate climate models
  - Deliver climate data to meet national needs

- *Climate models and data* support:
  - Agency needs: USGS, DOD, NOAA, EPA, USFS, …
  - Research: climate, weather, biospheric, …
  - Commercial interests: agriculture, fisheries, development, …

Thank you